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which are too vivid to be obliterated, while the mere description of apparatus and experiments learned out of books vanish away. Mathematical verbal rules are clearly remembered only by children already predisposed to mathematical learning, but learned by concrete examples, by weighing, measuring, and by true geometry dealing with concrete and truly-drawn plans of certain shapes, it becomes fixed in the mind, which is thus trained to make each particular experience lead up to the generalization which it cannot forget if it would.

The physiological basis of habit is not less obvious. "Inter-communicating nerve paths are marked out in the brain, . . . at every repetition of a movement or set of associated movements, the cells act more readily and with less effort of will, for the nerve paths become more clearly marked out, and impressions tend to slide more readily along them, until in time the movements or combined actions become almost unconscious or automatic. They have become habit, bad or good; they possess the body, which loses control over them. Transfer the picture to the intellectual sphere, and we see the same formation of mental habits as is found in the less mysterious muscular training."

Lastly, we may see here some light on the moral law, that it does not suffice to abstain from evil in act, but that all true repentance is a *μετανοια*, a turning of the desire by which internal energies are directed. For as surely as the voluntary calling up of the forbidden images in the mind stimulates the nerve flow, and directs it along channels which affect the whole system and lead to realization in act, so surely will that realization from time to time repeat the Fall, which immutably follows hard upon allowed Desire.

(To be continued.)

REASONS FOR STUDYING GEOLOGY.

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WHAT IS GEOLOGY? MISTAKEN NOTIONS AND PREJUDICES ABOUT IT.

THOSE who have tried to persuade others to take up the study of Geology, or who have had to do with arranging for public lectures on that subject, soon discover that it is not generally considered an attractive subject. Most people seem to regard it as a dull science, dealing only with dry bones and old shells, and they regard with mixed amusement and contempt the enthusiastic geologist tramping across the country, banging the rocks with his hammer, and filling his wallet full of stones and fossils. In fact, the common view of geology and geologists is pretty nearly that of the strong-minded and irascible hostess of the old hotel at St. Ronan's, in Scott's novel of that name, who expressed her contempt for the visitors at the "new hotel" by saying that "some rin up hill and down dale, knapping the chucky stanes wi' hammers, like sae mony road-makers run daft; they say it is to see how the world was made." The first thing to do, therefore, in trying to inoculate people with a proper appreciation of the delights of geology, is to disabuse their minds of the notion that it is "all fossils." Paleontology—that is, the study of the petrified remains of the vegetable and animal life of previous ages of the earth's history—is only *one* department of geology. It is an important one, it is true, for the fossils of certain plants and animals, being characteristic of certain strata, greatly assist the geologist in determining the ages, order, and character of the various strata, just as the architectural details of our cathedrals, abbeys, and churches enable us to determine the order of architecture and the age to which they should be assigned. It is as

if God had put those fossils in the rocks with the express design—

“To chronicle the ages back,
And notch His centuries in the eternal rocks.”

But geology has many other departments besides paleontology, and it has a very wide meaning and scope, as the very derivation of the word implies. The name, as most people know, is made up of two Greek words, *γη*, meaning the earth, and *λογος*, meaning a description or discourse. Geology, therefore, in its most extended signification, includes a study of everything relating to the earth, its origin and history as well as the phenomena which we now observe; its place in the universe as well as its internal structure; its constituent materials as well as its arrangements of surface; and among these constituent materials also the organic remains that we call fossils, as well as the soils and rocks in which they are embedded. The following is the definition given by one of our greatest geologists, Sir Charles Lyell:—“Geology is the science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature; it enquires into the causes of those changes and the influence which they have exerted in modifying the surface and external structure of our planet.” This is the technical and modern meaning of geology. We see, then, what a wide scope of investigation and study it presents to us. It is not an isolated, insignificant, subsidiary science, but it is an imperial science, which lays other sciences under tribute to minister to its investigations and resultant stores of knowledge, viz., cosmogony, which relates to the origin of the universe; astronomy, which tells of the earth's position in the universe; geography, which describes the divisions and appearances of its surface; chemistry, which reveals the composition and properties of the materials that form the earth; zoology and botany, which enumerate and classify the animals and plants which live or have lived on the earth. It is evident, therefore, that in geology we have a science whose family relationships are superlatively honourable and far-reaching, and whose claims on man's attention and interest ought to be placed in the first rank of the subjects of study in any system of education that pretends to be rational and liberal. The very fact that geology is, as we

have seen, the science which tells us the history, composition, and structure of the earth, supplies us with

THE FIRST REASON FOR STUDYING GEOLOGY:—THE EARTH IS OUR HOME.

Surely it is an astonishing and deplorable fact that so few of the lords of creation should be interested in that one among the innumerable worlds of the universe which is peculiarly their own domain, and on which they live, and move, and have their being. Just suppose that by some freak of a frolicsome fortune anyone of us were to learn this night that there had been bequeathed to him some famous historic mansion, belonging to one of the oldest and noblest families of the land, built by one of the world's greatest architects, enriched with priceless treasures of art, associated with great and romantic events of history, surrounded by an estate of vast extent and surpassing beauty and productiveness; should we not be impatient for to-morrow's dawn to set out to visit our noble inheritance? With what keen curiosity and doting interest we should gaze upon the spreading park and stately mansion, and wander from room to room, and examine every object of beauty and value, and study the general plan of the house and estate, and read up the chronicles of its eventful history and previous owners! And yet the eye is not brightened, the imagination is not kindled, the pulse is not stirred, by the gift of a whole world, which had God for its Architect, which has been in preparation for us during countless ages, and which is enriched with the priceless products of infinite wisdom and power. Surely such apathy is unreasonable, unnatural. Unreasonable—for multitudes flock to inspect and admire exhibitions of the masterpieces of human art and skill; even an Eiffel Tower, an auto-motor-car procession, a Lord Mayor's show, will attract gaping crowds, while God's handiwork is treated with stolid indifference as if not worthy of a look or a thought. This strange contrast suggests as

THE SECOND REASON FOR STUDYING GEOLOGY:—ITS BEARING ON RELIGION.

For this disproportionate appreciation of man's cleverness and this lack of interest in the works of an omnipotent Creator

is not only unreasonable, it is also a personal slight on God Himself. Whatever the Creator has thought it worth while to make is worth our while to study and to know. Just because it is a thought of God's mind, to which His omnipotent will has given form, everything in creation deserves to be an object of our reverent attention and thought. All God's works in nature have a sacred importance in the eyes of true believers just because they are God's works. If we care for Him, we shall care for the products of His infinite wisdom and power. Can we imagine the son of a great painter having no desire to see his father's pictures, the son of a great writer never reading his father's poems or tales, the son of a great commander never reading the history of the campaigns and battles by which his father won his world-wide fame? Lack of interest in the works of God, with which geology or any other branch of science makes us acquainted, indicates a lack of interest in God Himself. Such indifference is also closely akin to ingratitude, because these wonderful things which we ignore have been done "for our sakes," to minister to our needs, our happiness, our pleasure. Geology is a valuable aid to religion because it helps us, almost more than any other science, to realize the tender considerateness, the long forethought, the patient labour, the complex planning, on the part of God, of which we have been the unworthy but beloved objects. Geology shows us what a profuse expenditure of Divine wisdom and power has been bestowed upon the preparations and beautifying of this earthly home of ours during the countless ages of the great six days' creative week.

"My heart is awed within me, when I think
Of the great miracle which still goes on
In silence round me. The perpetual
Work of Thy creation. Finished, yet renewed
For ever."

THE THIRD REASON FOR STUDYING GEOLOGY IS ITS CONNECTION WITH SCENERY.

Many people have never realized that there is any connection between the two; but there is, and a very close one, too, viz., that of cause and effect. The configuration of the surface of a country, and all the principal features of its scenery, have their foundation and explanation in geological

circumstances. The relative position and scale of the elevations and depressions of the surface, the form and gradient of every hill, the peculiar character of every stream and waterfall, the variations of the coastline,—all depend mainly on the composition and structure of the rocks and the order of their succession, and are therefore explained by geology. As Professor H. G. Seeley says: "Every feature of headland or hill, bay or valley, which seems accidental, is the consequence of law, and every contour is in the position which it occupies, because the forces of nature have acted upon the resisting materials in such a way as to carve them differently." As a typical illustration of the close relationship between the geology and the scenery of a district as one of cause and effect, let me mention that when William Smith, who is called the "Father of English Geology," first saw the East Yorkshire wolds, it was from the top of York Minster, at a distance of twenty to thirty miles away. Yet he was able to determine, by his very first glance at them, to what geological formation they belonged. He recognized from the characteristic outlines of the range and contours of the separate hills that they were composed of chalk. He was an Oxfordshire man ("born upon the oolite," in 1769, at Churchill, and dying in 1839), and he knew nothing about the Yorkshire wolds before he saw them from York Minster. In a similar manner other formations also may be easily recognized by some of their characteristic effects on the landscape, by one whose eye and mind have had a geological training.* Surely many a tourist,

* These facts show how important some knowledge of geology is to a painter who composes landscape pictures. Without it he may easily make the mistake of grouping together incongruous features quite false to nature. He may represent plants that are characteristic of one formation as growing on another to which they are averse, *e.g.*, he may transfer the ling of the sandstone rocks to the limestone on which it will not grow. He may give to rocks and hills of one formation the structural forms and contours that are peculiar to those of a different kind. In waterfalls especially it is easy to go wrong, as each rock formation has its own typical falls. Whelan gives the following account of his detecting a mistake of this kind:—"I once burst into the studio of a clever artist, an intimate friend, and found him occupied in putting some finishing touches to a landscape composition. The general effect was pleasing enough, and the arrangement of light and shade exquisite. Still, when asked my opinion on the production, I was obliged to express dissatisfaction. My friend slightly coloured. 'What was it that offended me?' 'Want of congruity,' I replied; 'want of truthfulness to nature. Even had I not been expressly informed of the fact, I should have been assured that it is no real landscape that is here portrayed.' I then questioned him as to his summer ramblings. 'Had

when visiting one of the beautiful districts for which our land is famous, and enjoying the fine scenery, must have sometimes felt the instinctive desire of intelligent curiosity stirring his mind to ask such questions as these,—How came the surface of the earth to be so beautifully diversified? why some mountains have regular slopes and others are precipitous and rugged? why some valleys are wide and open and others narrow and rocky? how it is that rivers so often cut through ranges of hills higher than the course and source of the rivers themselves? why some extensive tracts of hills are uniformly covered with the purple ling and others with short fine grass? what forces elevated and sculptured the long lines of rock escarpments overlooking the valleys? and many other similar questions. What a pity that they do not proceed to ascertain the answers to such questions by taking up the study of geology! We ought not to be content to go through life

he ever sketched in Kent?' 'Yes, many a time.' 'Had he ever visited Wales or Cumberland?' 'Yes, both.' 'Perhaps he had crossed over to the Isle of Man?' 'Yes, he had some Manx sketches in his portfolio.' 'And, therefore,' I continued, 'in composing this picture from your note-book, you have placed on one side of your lovely Kentish valley, with its hazel copses and hop-clad slopes, the towering porphyritic peaks of Scawfell and Great Gavel, and on the other the beautifully rounded outline of Ben-y-Phot or Greebah, the softer clay-schists of whose surface have been ploughed up by the passage over them of ice-floes and icebergs, and then degraded during ages of quiet upheaval from the depths of an arctic sea. And see,' I added, 'this mass of rock which so picturesquely occupies the foreground, and is supposed to have been detached and to have fallen from this frowning *porphyritic* precipice, is a veritable lump of *mountain limestone*, one of the blocks which the action of the boisterous sea which beats on the ironbound coast of old Mona, has torn down from the singular patch of limestone which juts out between Port St. Mary and Perwick Bay.' My friend, with his characteristic candour, owned the correctness of my remarks, and acknowledged that to be a proficient in his art, he ought either to paint direct from nature, or, if he composed a picture, to become a geologist. Perhaps some might be inclined to exclaim, '*Cur ego amicum offendam in nugis?*' 'Why get in a passion with such things as these?'; or, with the same classic author to affirm that 'to poets and painters sufficient liberty must be allowed.' Granted; yet our old friend Horace is quite as decided as to the necessity of unity in a poem or a picture; and that man as much offends against true art, truth, and nature itself, who paints a granite peak atop of a chalk cliff, as he who portrays 'a dolphin in the woods, or a wild boar in the midst of the sea.' The fact is that both poets and painters of some eminence have been guilty of many (so to speak) geological anachronisms. The terms granitic and adamantine sound very grand, and help to round a line, if they do not always express a truth; and so, also, it is very easy to paint gigantic breakers dashing against impossible coasts, and from ignorance of the effects of the atmosphere on rocks of different texture, to display on the same canvas such an aggregation of scenery as it is not likely, if at all possible, should occur on the face of nature."

blindfold, or looking only on the surface of things. As it has been well said: "He who loiters through a noble library, content with seeing the backs of the volumes in their fine carved cases, admiring their beauty and delicate finish, but satisfied with such superficialities, and caring nothing for what lies behind the beauty of the binding, is little removed from the man who admires external and superficial nature, with no care for the greater beauties and greater truths that lie beneath the surface." We should not be content to admire, but also be ardent to know; the wonder of ignorance is not to be compared with the more exalted and exquisite wonder that is begotten of knowledge. They who understand the geology of a district have a double pleasure; they appreciate the scenery all the more because they have a knowledge of cause as well as of effect. As Professor Philipps assures us, there is no need to fear that "the charm of fine scenery will be diminished because the secret agencies which have concurred in its production have become familiar to the reasoning geologist. Surely he, of all men, should be the most affected by the charms of nature who, in addition to the pleasure derived from contemplating the external aspect of creation, feels himself irresistibly led to connect the present configuration of the surface of the earth with great changes in its exterior and interior conditions, to unite the present with the past, and to view the manifold revolutions which have visited the earth as in no sense accidental, but parts of one general and continuous plan, singularly adapted to the moral and intellectual capacity of man." Indeed geology does not lessen, it heightens the poetic enjoyment of nature, for it uplifts the veil from the outward beauty of the world, and reveals what would otherwise be hidden, the agencies which, operating in bygone times, produced these varying scenes of delight. Thus it links together the wonders of the past and of the present, and invests the most familiar objects with the glow and halo of imagination. It enables us to say, in the words of Chatterton,

"These are Thy wondrous works, first source of good,
Now more admired in being understood."

Therefore I strongly recommend all lovers of nature to take up the study of geology, being confident from my own experience that "no one can receive all the pleasure afforded

by natural scenery until he has learned in some degree to interpret its history, *i.e.*, its geology."* Then, when you have acquired even an elementary knowledge of the subject, you should take with you on your annual holidays a geological map of the district which you are visiting, and by its aid you can study the physical features of all the area within your reach.† "No one but he who has tried it can realise how vastly a man's mental horizon is extended, how his resources are multiplied by even an elementary knowledge of geology." No one need be deterred by the fear that he will find it too difficult; most of it is as easy as it is interesting. "Speak to the earth and it shall teach thee." (Job xii. 8.)

Moreover, we who are inhabitants of the British Isles have as

A FOURTH REASON FOR STUDYING GEOLOGY:—THE FACILITIES AFFORDED BY OUR OWN COUNTRY.

For in no country in the globe do such exceptional advantages exist for attaining a practical acquaintance with almost every variety of rock, with almost every formation; as you may see for yourselves if you look at a geological map of the British Isles and observe the variety of colours, indicating the many formations of which our country consists, and remember its limited extent, and the swift and easy communications with every part of it which we can avail ourselves of. Professor Archibald Geikie speaks strongly on the exceptional advantages which British students of geology enjoy. He says:—"Perhaps no part of the earth's surface comprises within the same area so complete an epitome of the structure of the rocky crust of our planet, as is to be found within the compass of the British Islands. The geological formations which in other countries spread out over hundreds and thousands of square leagues, are here brought within such narrow limits that a single English

* Article on "Craving for Fiction," *Nineteenth Century*, June, 1893, p. 1058.

† Whelan says:—"For a tourist to enter upon a district, guide book and map in hand, but that guide book or map defective in geological description or colouring, is much the same as if he should walk into a picture gallery, with a catalogue of its contents, but that catalogue unnumbered, or the numbers so placed as not to correspond with the tickets attached to each separate painting."

county contains within itself a greater variety of rocks than can be seen in some whole kingdoms abroad. In this way, without quitting his country, a native of Great Britain may often obtain, from an examination of the rocks around him, a more correct and vivid conception of the nature of geological reasoning, and of the grandeur of geological history, than if he travelled hundreds of miles in some countries." For instance, in Russia the traveller may journey a thousand miles or more without meeting with a crag or dell. The ground he passes over does not shift its level more than a hundred feet, and it all belongs to the same geological formation.

Professor Ramsay also writes to the same effect:—"England is the very paradise of geologists, for it may be said to be in itself an epitome of the geology of almost the whole of Europe, and of much of Asia and America. Very few European geological formations are altogether absent in England. In some countries, larger than England, the whole surface is occupied by one or two formations, but in England nearly all the formations are more or less developed." Such is the testimony of two of our leading geologists. In this respect, indeed, as in many others, our own country is a "microcosm," a world in miniature. In fact, "it seems as though our island had been placed in a corner of Europe to serve the purposes of an index map to the continental formations."

CONCLUSION.

Much more might be said, if space permitted, to emphasize the importance and interest of the study of geology, but surely sufficient reasons and inducements have been presented to persuade any intelligent person, who has the opportunity, to go read for himself "the great stone book of nature"—"the story-book thy Father has written for thee."

"Oh, that we had eyes to see
The glory that around us lies;
To read the secrets of the earth,
And know the splendour of the skies."